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TREATMENT

Radiography in pediatric dental practice

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Abstract
Dental radiography plays an important role in diagnosis, treatment planning, dental procedures, and treatment follow-up. Two-dimensional imaging is the gold standard, and in case the diagnostic yield from these is not sufficient, additional three-dimensional imaging can be used [e.g., cone beam computed tomography (CBCT)]. This manuscript describes intraoral and extraoral radiography techniques that can be applied in every day pediatric dentistry. Knowing and understanding the techniques and being aware of their limitations are paramount in making the right decision to obtain the best diagnostic image in every individual case.

Keywords Pediatric radiography · Intraoral radiography · Extraoral radiography

Quick reference/description

Pediatric dental practice is incomplete without the various radiographic techniques. These techniques are important adjunctive tools for establishing a definitive diagnosis. Radiographic techniques can be intraoral or extraoral depending on the purpose of the imaging and the patient's ability to tolerate the procedure.

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Overview

Imaging modality	Indications
Intraoral radiography	
Periapical radiography (parallel technique or bisecting angle technique) [P] Bitewing radiography [B] Occlusal radiography [O]	Caries diagnosis [P, B] Alveolar bone assessment [P, B] Dental development [P, O] Dental eruption [P, O] Periapical pathology [P, O] Bone pathology [P, O]
Extraoral radiography	
Oblique lateral radiography	Alternative to intraoral radiography if patient cannot tolerate intraoral positioning of the image detector (good alignment required between image detector and X-ray source for adequate caries diagnosis)
Panoramic radiography	Alternative to intraoral radiography if patient cannot tolerate intraoral positioning of the image detector (extraoral bitewing is possible) Dental development Bone pathology Periapical pathology
Cephalometric radiography	Orthodontic analyses and planning Orthognathic surgery planning
Cone beam computed tomography	When two-dimensional imaging is insufficient and only three-dimensional imaging can add missing diagnostic information

Materials/instruments

- Intraoral X-ray unit
- Image detectors
- Image detector holders
- Wooden tongue depressors
- Stiff cassettes for image detectors
- Panoramic X-ray unit
- Cephalometric X-ray unit
- Cone beam computed tomography (CBCT) X-ray unit

Procedure

Radiography is an invaluable component of pediatric dentistry for establishing a diagnosis. Based on the patient's tolerability towards the procedure and the aim of imaging, radiographs can be taken intraorally or extraorally.

Intraoral radiographic techniques

Intraoral radiography is an essential tool in pediatric dentistry for the diagnosis of various dental conditions. This approach includes extraoral placement of the X-ray machine and intraoral placement of the image detector. The X-ray machine is directed towards the image detector, which is positioned close to the teeth to obtain an image of minimal distortion and optimum quality. Intraoral radiographs can be obtained using the parallel technique, the bisecting angle technique, and the occlusal technique. Ideally patients should be positioned upright in the dental chair to have their intraoral radiographs taken.

Parallel technique

In the parallel technique, the image detector is placed as parallel and close to the teeth as possible with the X-ray beam being projected perpendicular to the image detector (Fig. 1). In case of anatomical variations in the shape of the palate, level of the floor of the mouth or presence of tori, etc., the image detector cannot be positioned in contact with the tooth.

An image detector holder is used for appropriate alignment of the image detector and the X-ray machine. The image detector should fit snugly in the holder without damaging it. Various brands of image holders, like Rinn® (Rinn® XCP kit for analog

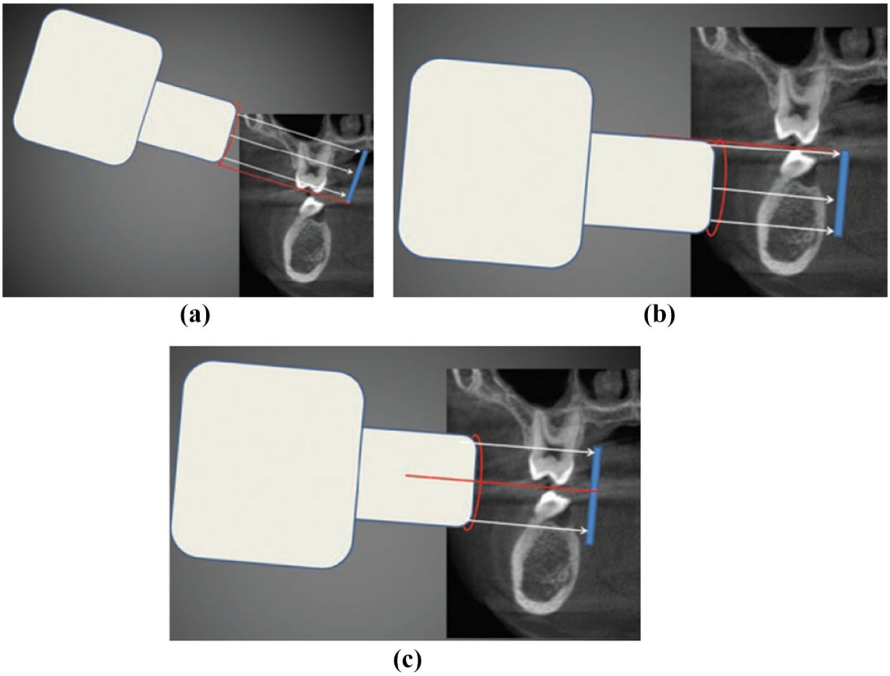


Fig. 1 Schematic illustration of parallel technique: **a** maxillary molar, **b** mandibular molar, and **c** bitewing X-ray

film) and Hawe Neos®, are available all over the world and should be matched with the appropriate image detector.

The advantages of this technique are:

- resultant geometrically accurate images of the teeth and alveolar bone;
- presence of an extraoral guide or aid for the X-ray machine.

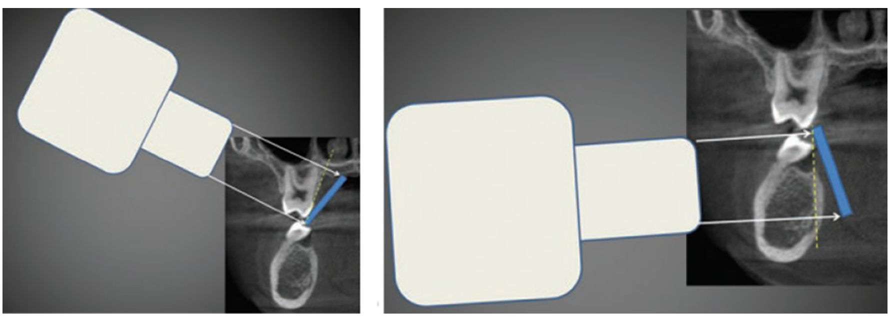
Bisecting angle technique

In the bisecting angle technique, the X-ray beam is directed perpendicular to an imaginary bisecting line drawn between the long axis of the image detector and the long axis of the tooth (Fig. 2). The image detector is placed at an angle against the teeth. This technique is usually used when the patient cannot tolerate the placement of the image detector parallel to the teeth. Rinn® BAI (bisecting angle instrument) is an image detector holder that is currently available for use in the bisecting angle technique.

Occlusal technique

The occlusal radiographic technique is an alternative approach to the parallel or bisecting angle technique. A photostimulable phosphor storage plate is used to produce occlusal radiographs. Size-2 plates are used for primary teeth and size-4 plates can be used if more anatomy needs to be visible. The patient should be advised not to bite on the phosphor storage plate to prevent bite marks. A simple technique for protection of phosphor plates against bending and bite marks is taping two wooden tongue depressors on the plate (Fig. 3). Using the tongue depressors is also beneficial as it shows the tilting of the occlusal plane better and it helps assessing the correct angulation of the X-ray machine.

Occlusal radiograph of the Maxilla An occlusal radiograph of the anterior maxilla is usually indicated in cases where the parallel technique is challenging (e.g., dentoal-



(a) (a)

Fig. 2 Schematic illustration of bisecting angle technique: **a** maxillary molar and **b** mandibular molar. The yellow dotted line represents the imaginary bisecting angle between the tooth and the image detector

Fig. 3 Protecting the phosphor storage plates from bite marks with wooden tongue depressors

veolar trauma). Since the primary X-ray beam is pointing down in the direction of the thyroid gland, it is recommended to have the patient wear a thyroid protection collar or shield. The maxillary occlusal radiograph is performed as follows (Fig. 4):

– The patient is positioned upright in the dental chair, and the phosphor storage plate is placed on the occlusal plane. Ensure that the occlusal plane is parallel to the floor.

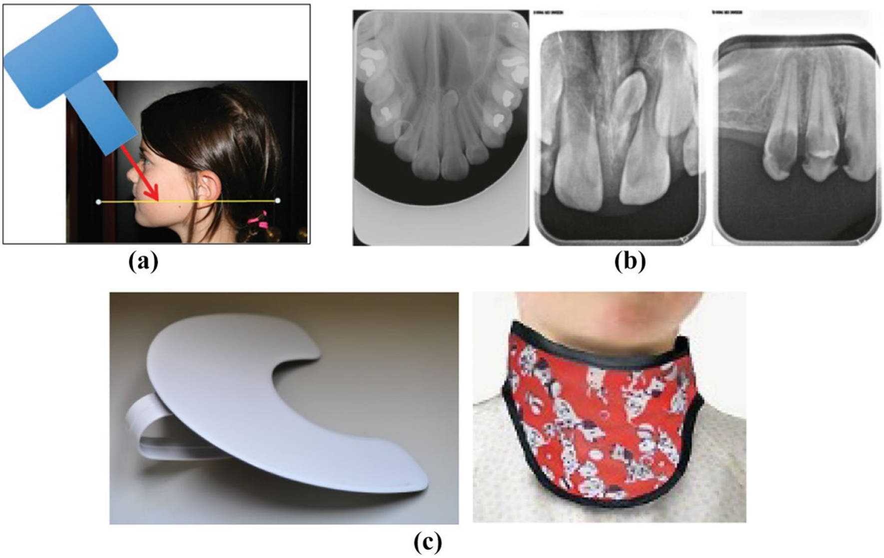


Fig. 4 **a** Illustration of the standard occlusal technique (yellow line represents the occlusal plane and the red arrow represents the X-ray beam aimed through the bridge of the nose at a 65° angle with the occlusal plane). **b** Occlusal radiographic images of the maxilla: left-hand-side image with a size 4 plate, middle and right-hand-side images on size 2 plates. **c** Examples of a radiation protective thyroid shield that can be held under the chin or a collar that can be worn around the neck

- The head of the X-ray tube is aligned at a 65° downward angle. The X-ray tube spacer cone is positioned at the bridge of the nose for anterior teeth resulting in an occlusal view of the maxillary arch (Fig. 4).
- The X-ray tube head is also angulated at a 65° downward angle for viewing the posterior teeth. Only difference with before is that the position of the head of X-ray tube is shifted to the side to be radiographed.

90° occlusal radiograph of the mandible A view of the entire floor of the mouth and the circumference of the mandible are obtained in a 90º occlusal radiograph (Fig. 5). It is a classic approach for the imaging of swellings on the buccal or lingual mandibular aspects, foreign bodies in the floor of the mouth and sialoliths in the submandibular salivary glands. The procedure is as follows:

- The patient is positioned upright in the dental chair. The occlusal plane is aligned perpendicular to the floor by instructing the patient to tilt the chin upwards. Alternatively, the patient can also be placed in a supine position in the dental chair and the head position is adjusted till the occlusal plane is perpendicular to the floor.
- The phosphor storage plate is placed on the occlusal plane (its long axis transverse or longitudinal), while the head of the X-ray tube is aligned perpendicular to the plate.

45° occlusal radiograph of the mandible The 45° occlusal radiograph of the mandible is usually performed to obtain an image of the anterior mandibular teeth (Fig. 6). It is a more comfortable technique for the patient than the periapical or bisecting angle approach. The procedure is as follows:

- The patient is positioned upright in the dental chair. The phosphor storage plate is positioned on the occlusal plane. Ensure that the occlusal plane is parallel to the floor.

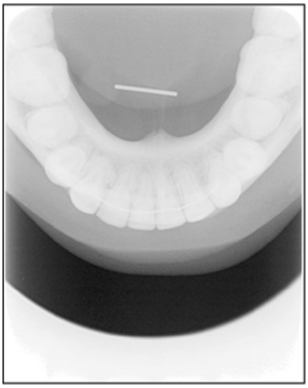
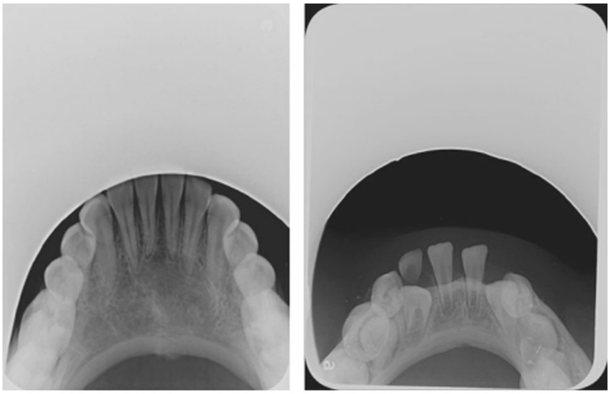


Fig. 5 Illustration of 90° angle occlusal image of the mandible (adolescent patient sustained trauma resulting in lodging of a metal rod in the floor of the mouth)



(a) (b)

Fig. 6 45° Occlusal radiograph of the mandible

– The X-ray tube head is angulated at a 45° upward angle and aimed through the chin.

25°–30° occlusal radiograph of the mandible The 25°–30° occlusal radiograph of the mandible is usually performed to obtain an image of the posterior mandibular teeth. It is beneficial in young patients and in those, who are unable to tolerate the placement of the image detector parallel to the teeth (Fig. 7). It is performed as follows:

– The patient is positioned upright in the dental chair. Ensure that the occlusal plane is parallel to the floor.
– The patient is instructed to turn the head towards the opposite side to provide adequate space for the X-ray tube between the patient's chest and shoulder.
– The head of the X-ray tube is titled at a 25°–30° upward angle.

Extraoral radiographic techniques

Extraoral radiography is also an important tool for the diagnosis of various dental conditions in pediatric dental practice. This approach includes extraoral placement of the X-ray machine and image detector in proper alignment for optimal image quality. Extraoral radiographs can be produced by keeping both the X-ray source and the image detector stationary or by synchronized movement of the image detector and the X-ray source in opposite directions. The various techniques are panoramic imaging, cephalometric imaging, oblique lateral radiographs, and CBCT imaging.

Dental panoramic tomography

Dental panoramic tomography is also known as a DPT, an OPG, a pan, or a panorex. In panoramic imaging, the image detector and the X-ray source move in opposite directions in a synchronized manner. The image detector passes as close

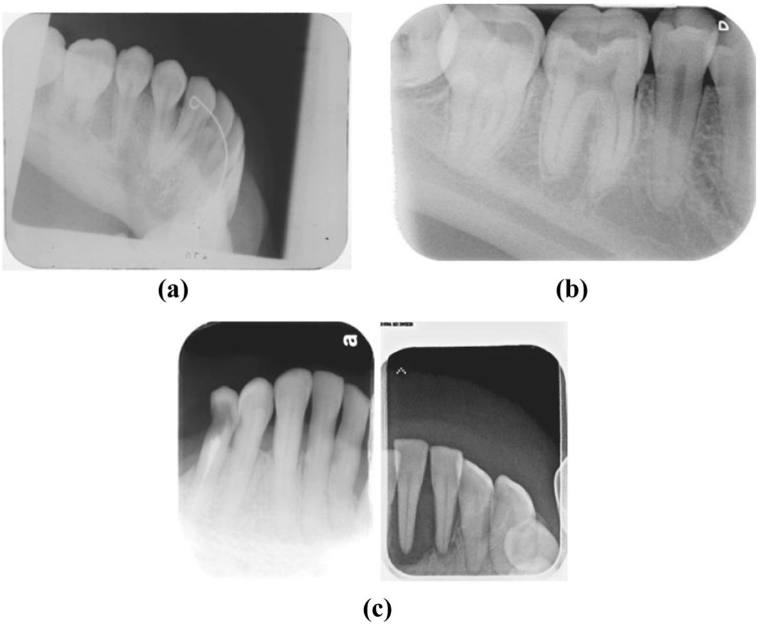


Fig. 7 25°–30° Occlusal radiograph of the mandible

to the patient's face as possible. A horse shoe-shaped focal trough or slice of particular thickness is created by this movement.

In dental panoramic radiography, a vertical narrow slit of X-ray beam is used. Collimation of the X-ray beam in height is essential to reduce radiation exposure in children. Some machines also allow blockage of image segments. The X-ray beam is angulated slightly upwards (8°–12°) (Fig. 8).

Optimal image quality critically depends on patient positioning. Patient positioning requires strict adherence to the manufacturer's instructions. Inadequate patient positioning can result in the panoramic image appearing 'smiling' due to

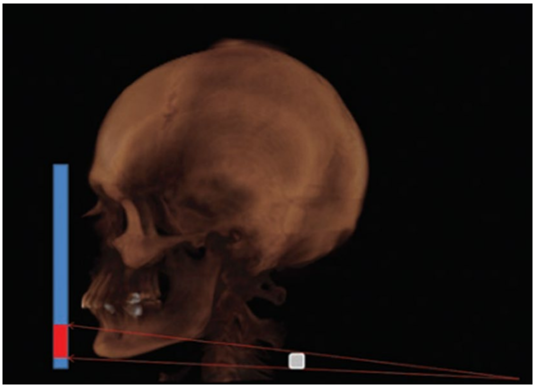


Fig. 8 Schematic illustration of the angled X-ray beam and the projection on the chin of structures in the neck: the gray square in the neck casts a shadow over the anterior part of the mandible. The blue rectangle represents the image detector and the red rectangle shows where the projection of the gray square will be superimposed over the real image of the mandibular symphysis

the Frankfort plane tilting down in the front in a low chin position, or the image appearing 'sad' due to the Frankfort plane tilting down to the back in a high chin position. In a short patient or a small child, a step stool can be used to position the patient (Fig. 9).

For the required straight neck position, the patient is instructed to shuffle the feet forward, while their back is supported by the operator, till the tips of the shoes coincide with the same vertical line as their hands that are holding the handle bars. The anterior–posterior patient positioning in the machine differs with the different sizes of the focal trough (horseshoe-shaped) in different radiography machines. The midsagittal plane of the patient's skull should be perpendicular to the floor and in the middle of the machine. Identification of the normal anatomy is essential to diagnose pathology or abnormal anatomy (Fig. 10).

Prior to positioning the patient, one has to ensure that there are no foreign objects that can affect the image quality. For instance, hair pins, hair clips, ear rings, lip and nose piercings, tongue piercings, removable orthodontic appliances, etc. Foreign objects above the orbits can be left in place, as these will not interfere with the final image.

Once the patient is positioned in the machine, the following instructions are essential:

- keep the lips closed
- swallow and keep tongue against the roof of the mouth
- do not move until instructed to step out of the machine.

The patient should be instructed properly about their positioning for a satisfactory outcome of the imaging procedure.

Panoramic or extraoral bitewing radiographs Extraoral bitewing radiographs or extraoral periapical radiographs (author's term) can be produced by certain panoramic

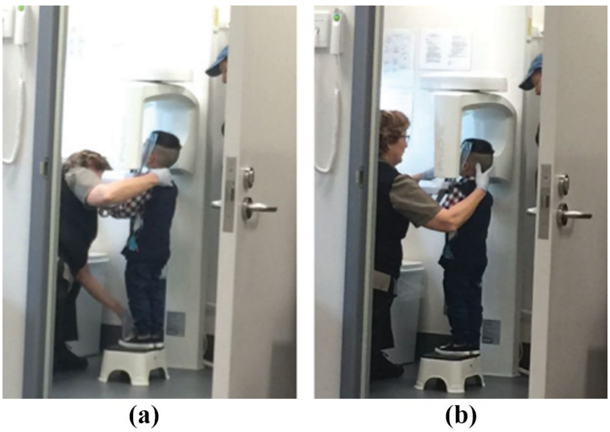


Fig. 9 Four-year-old boy standing on a step stool, while the dental radiographer is positioning the patient

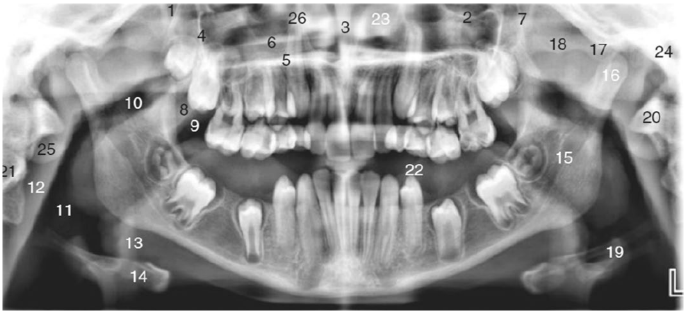


Fig. 10 Identification of anatomical landmarks on a panoramic radiograph: (1) pterygomaxillary fissure, (2) inferior border of orbit, (3) nasal septum, (4) zygomatic buttress of maxilla, (5) real image of the hard palate or floor of the nose, (6) ghost image of the hard palate, (7) posterior wall of maxillary sinus, (8) soft palate, (9) air space between tongue and soft palate, (10) air space of nasopharynx, (11) air space of pharynx, (12) posterior wall of pharynx or anterior lining of the cervical spine, (13) tongue, (14) hyoid bone, (15) inferior alveolar canal, (16) mandibular condyle, (17) articular eminence, (18) zygomatic arch, (19) epiglottis, (20) anterior process of atlas, (21) body of axis, (22) open lips, (23) inferior nasal concha, (24) external acoustic meatus, (25) ear lobe, and (26) lateral wall of nasal cavity or medial wall of the maxillary sinus

radiography machines, and can be indicated for patients who are unable to tolerate intraoral radiographs (Fig. 11). These radiographic images show more information than intraoral bitewings. To produce an image of optimal quality, patient positioning as per the manufacturer's instructions is crucial to avoid interproximal overlapping.

Cephalometric imaging

Orthognathic surgery and orthodontic treatment planning commonly require cephalometric radiographs. A unique objective of cephalometric radiographs is that it should be reproducible, because particular structures in the skull (sella turcica) have to be used as reference for verification of growth or effect of disease or surgery.

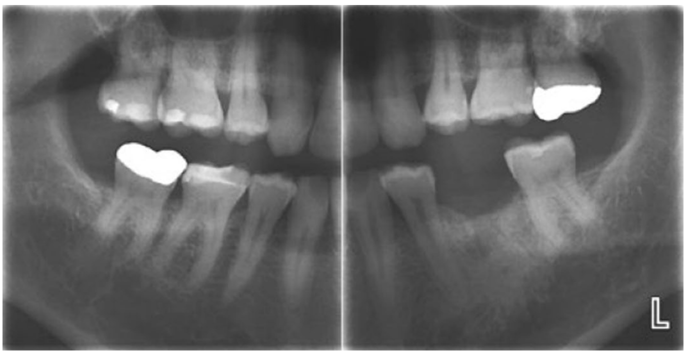


Fig. 11 Extraoral bitewing radiograph (courtesy of James Hughes, Planmeca® USA)

A specialized X-ray machine with a cephalostat is used for appropriate patient positioning in cephalometric imaging. It allows production of reproducible lateral skull view images. The cephalostat contains two ear rods that are inserted into the external acoustic meatuses to align the midsagittal plane of the skull perpendicular to the floor and a support on the bridge of the nose to maintain the natural position of the patient's head. The patient's teeth are occluded during the imaging.

Various types of cephalometric X-ray machines are available from different manufacturers that use different techniques like a one-shot method to avoid motion artifacts, anterior–posterior, or vice versa scan of the skull. Collimated X-ray fields to reduce radiation exposure are available, as well. The cephalostat can be rotated and permits several skull radiographic projections:

- anterior–posterior skull
- posterior–anterior skull
- submento-vertex skull
- any deviation or variation of the former positions.

Cephalometric images should always be viewed with the patient facing towards the right side. The soft tissues overlying the face and neck should also be visible on cephalometric images for treatment planning in orthognathic and orthodontic analyses.

Oblique lateral radiograph

An oblique lateral radiograph is an exceptional tool for diagnosis in pediatric dentistry when used by an experienced operator. It is also a valuable diagnostic approach in patients with special health care needs. To produce an oblique lateral radiograph, the intraoral radiography X-ray machine with an exposure time of 0.16 s at 65–70 kV and a stiff cassette fitted with a phosphor storage plate are used.

Oblique lateral radiographs are an alternative radiographic technique only when patients are intolerant to periapical or bitewing radiographic imaging. The method is as follows (Fig. 12):

- A stiff cassette with a phosphor storage plate is held in contact with the patient's cheek and the tip of the nose against the side of the face required to be imaged. Ensure that a part of the cassette is positioned below the inferior border of the mandible.
- It can also be performed on a patient under general anesthesia by taping the cassette to the patient's head. It is important to ensure that the cassette is leaning against the patient's nose and cheek during X-ray exposure.
- The patient is instructed to turn the head to the side to be imaged. These positions of the head and the cassette result in a radiographic keyhole on the opposite aspect between the posterior border of the mandibular ramus and the cervical spine.
- The X-ray machine is fitted with a circular collimator. The X-ray tube head is aligned perpendicular to the cassette. The lips are used for guiding the central

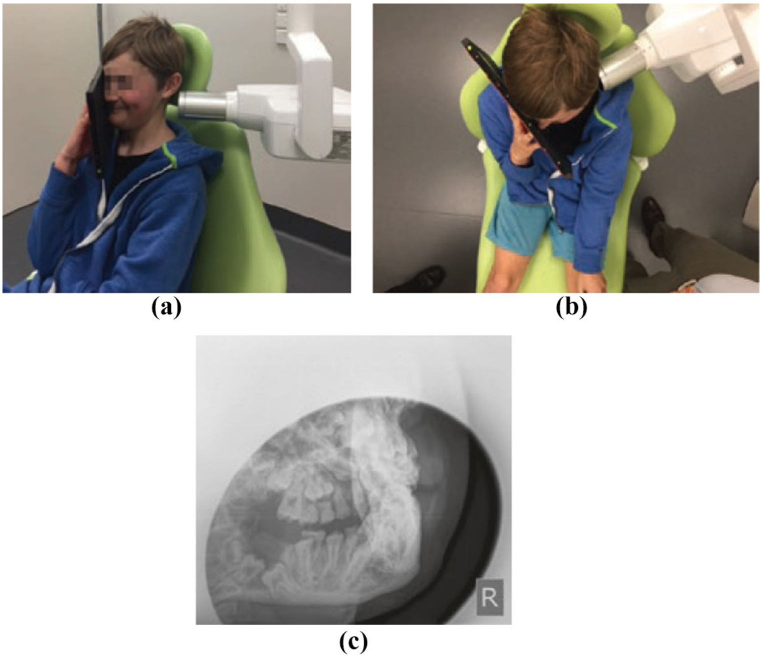


Fig. 12 Oblique lateral radiograph. **a** X-ray beam perpendicular to the cassette held against the patient's cheek and nose. **b** Bird's view perspective of patient and X-ray tube head positioning. **c** Oblique lateral radiograph taken in a child with autism spectrum disorder and eruption issues

X-ray beam to follow the occlusal plane. A perfect circular image is then produced if the geometry is accurate.

Cone beam computed tomography

Cone beam computed tomography (CBCT) involves a conical (pyramidal) X-ray beam revolving around the patient's head in a single rotation, while the image detector moves on the opposite aspect of the skull in a synchronized manner. The result is a three-dimensional image in the form of a cylinder. The field of view should be as close as possible to the area of interest, to keep the radiation dose as low as possible. To obtain the area of interest in the center of the scan volume, the pivoting point or rotation axis should be decided and suitably positioned.

Cone beam computed tomography can be used in pediatric dental practice for patients with cleft lip and palate (orthognathic surgery in general), in cases of complicated dentoalveolar trauma, eruption issues, and endodontic complications, for instance, when conventional two-dimensional imaging is insufficient in providing crucial diagnostic information. CBCT is not indicated for soft-tissue pathology diagnosis. Several manufacturers permit a change in the field of view or size of the scanned volume, and some machines also allow alteration of the rotation arc of the machine from 360° to 180°.

The resolution of the image should be decided prior to X-ray exposure as it depends on the purpose of CBCT assessment. A low-resolution image (400–200 μm) is adequate for eruption issues or root resorption, while a high-resolution image (75 μm) is required in endodontics.

To obtain an image of enhanced quality with a optimal diagnostic yield, it is crucial that the patient remains still during X-ray exposure.

The CBCT radiographic technique produces a 3D image. The image is visualized and can be analyzed in three orthogonal planes: sagittal, coronal, and axial. A 3D reconstruction of the image can also be produced by most software manufacturers. The acquired image volume is reoriented to view the image in all three planes and different software applications (e.g., windowing, paging, and ray sum) can subsequently be used to assess the images (Fig. 13).

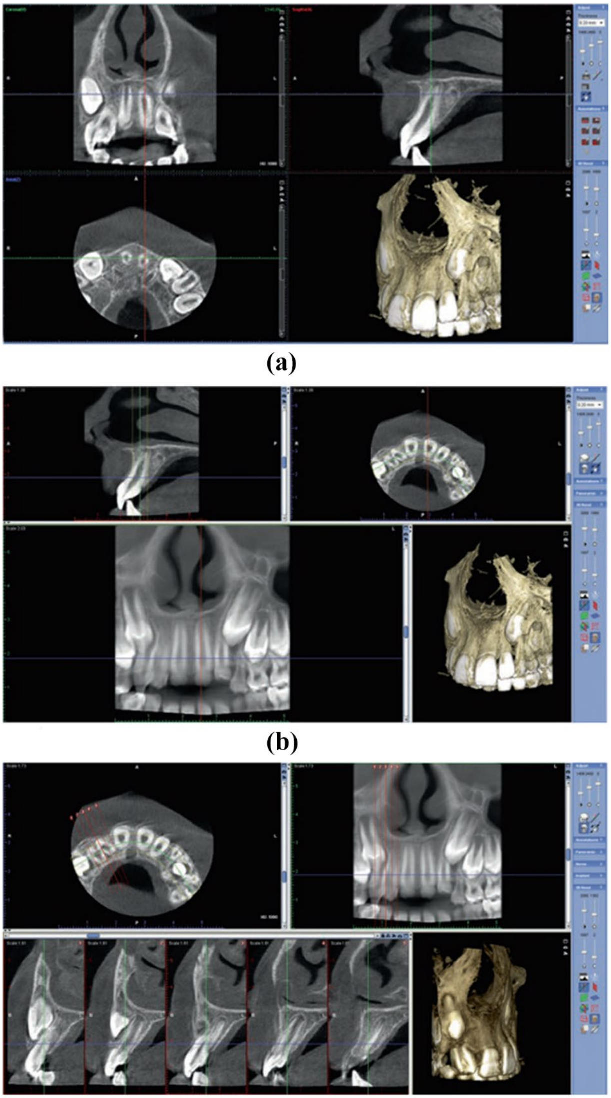
One has to take into account that CBCT is subject to artifacts caused by radiopaque materials (e.g., gutta percha or metal prostheses, jewellery in the head and neck region, and hair clips inside or outside the field of view). These artifacts can result in axial streaking that can mimic fracture lines and impair evaluation of possible root fractures in endodontically treated teeth. Therefore, all metal containing items should be removed prior to a CBCT imaging.

Currently, there is no standardization regarding exposure parameters and field of view, which makes comparison of radiation doses among the various CBCT machines very difficult.

Pitfalls and complications

- The best intraoral radiograph is taken with the parallel technique. If that is not feasible, one has to follow a cascade of possible techniques (Fig. 14), with the bisecting angle technique, the occlusal technique, and if possible the oblique lateral technique. The latter technique requires extra equipment and there is definitely a learning curve.
- Extraoral bitewing radiography with panoramic machines can be a good alternative if intraoral bitewings are impossible. Patient positioning is crucial though.
- Panoramic radiography is always subject to magnification and ghost images. Patient positioning in panoramic radiography is key.
- Two-dimensional imaging is still the gold standard. Three-dimensional imaging is an adjunct to two-dimensional imaging and should never be used as the first choice.

Every radiographic exposure, whether two- or three-dimensional, must be justified and its benefits should always outweigh the potential risks. The latter dovetails into radiation protection principles, which are equal for all patients: justification, limitation, and optimization. One has to be able to justify the exposure, which includes that the patient should be able to cope with the procedure. The limitation principle goes hand in hand with the optimization principle, as one has to try to obtain the best image quality possible while keeping the radiation as low as diagnostically achievable (ALADA). The latter can be taken a step further and should



(a)

(b)

(c)

Fig. 13 **a** A typical CBCT screen with three orthogonal planes and 3D reconstructed image of the scan. **b**, **c** The panoramic reconstruction of the same volume and some of the transverse slices

be customized to each individual patient (ALADAIP). The best way to reduce the radiation dose in intraoral imaging is to use rectangular collimation. Protection of the thyroid gland should be practiced at all times and other protective gear (e.g., lead apron) should only be used, in case non-target tissues would fall in the primary X-ray beam. The latter is almost never the case in dentistry, except in occlusal radiography, where the primary X-ray beam may be directed at the thyroid gland.

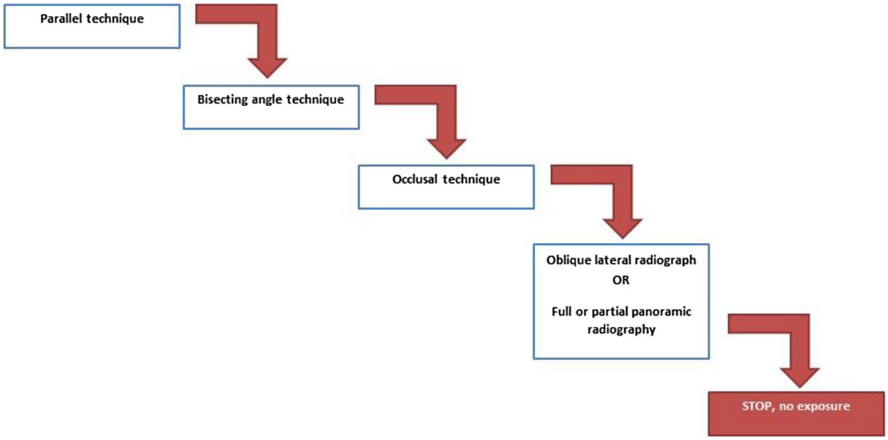


Fig. 14 Cascade of possibilities for intraoral radiographs

Table 1 Typical effective doses from dental and medical diagnostic exposures/examinations

X-ray examination	Effective dose (*E*) in mSv	Effective dose (*E*) in μSv
Bitewing/periapical radiograph	0.0003–0.022	0.3–22
Panoramic radiograph	0.0027–0.038	2.7–38
Upper standard occlusal	0.008	8
Lateral cephalometric radiograph (dental)	0.0022–0.0056	2.2–5.6
Posterior–anterior skull radiograph	0.02	20
Lateral skull radiograph (medical)	0.016	16
Posterior–anterior chest radiograph	0.014	14
Lateral chest radiograph	0.038	38
CT skull	1.4	1400
CT chest	6.6	6600
CT abdomen	5.6	5600
CT maxilla and mandible	0.25–1.4	250–1400
Barium swallow	1.5	1500
Barium enema	2.2	2200
CBCT small/medium field of view	0.01–0.67	10–670
CBCT large field of view (craniofacial scan)	0.03–1.1	30–1100

Regarding guidelines on dental radiography in children, the 2019 EAPD guidelines are very clear. There is no justification for routine dental (two- and three-dimensional) radiography, nor is there a set age for when the first X-rays should be taken. The justification and ALADAIP principles are key.

Effective radiation doses from different diagnostic radiographic examinations can be found in the table (Table 1). One can appreciate that dental diagnostic radiation doses are much lower compared to several medical diagnostic examinations that use ionizing radiation.

Further reading

1. Aps J (2019) Imaging in pediatric dental practice. Intraoral radiography in pediatric dental practice. https://doi.org/10.1007/978-3-030-12354-3_3
2. Aps J (2019) Imaging in pediatric dental practice. Extraoral radiography in pediatric dental practice. https://doi.org/10.1007/978-3-030-12354-3_4
3. Whaites E, Drage N (2015) Essentials of dental radiography and radiology, 5th edn. Churchill Livingstone, Elsevier, London
4. Graham DT, Cloke P, Vosper M (2016) Principles of radiological physics, 6th edn. Churchill Livingstone, Elsevier, Amsterdam
5. Oenning AC, Jacobs R, Pauwels R, Stratis A, Hedesiu M, Salmon B, on behalf of DIMITRA Research Group (2018) Cone-beam CT in pediatric dentistry: DIMITRA project position statement. Pediatr Radiol 48:308–316. http://www.dimitra.be. Accessed 1 Feb 2019
6. Pauwels R, Seynaeve L, Henriques JCG, de Oliveira-Santos C, Souza PC, Westphalen FH, Rubira-Bullen IRF, Ribeiro-Rotta RF, Rockenbach MIB, Haiter-Neto F, Pittayapat P, Bosmans H, Bogaerts R, Jacobs R (2015) Optimization of dental CBCT exposures through mA reduction. Dentomaxillofacial Radiology. 44:20150108
7. White SC, Pharoah MJ (2014) Oral radiology. In: Principles and interpretation. 7th edn. Elsevier, St Louis
8. Kühnisch J, Anttonen V, Duggal MS, Spyridonos ML, Rajasekharan S, Sobczak M, Stratigaki E, Van Acker JWG, Aps JKM, Horner K, Tsiklakis K (2019) Best clinical practice guidance for prescribing dental radiographs in children and adolescents: an EAPD policy document. Eur Arch Paed Dent 10:10. https://doi.org/10.1007/s40368-019-00493-x)